Development of a Multi-Block Interface for a High-Order Compact Scheme Applied to Sound Scattering Problems in Aeronautics: Part I

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Context

Airport movements are limited by aircraft noise emissions that are a major obstacle to the sustainable development of aircraft operations. Specific stringent near-term noise reduction goals (1) are driving active research in aeroacoustics, such as through the AeroTraNet consortium (http://www.imft.fr/aerotranet/) funded by the European Community's Sixth Framework Programme (FP6).

The traditional aircraft design approach is to consider the steady flow aerodynamics and the sound generated aerodynamically as separate entities. This split is artificial, as, in general, it is not possible to unambiguously separate the ''flow'' from the ''sound'', which are physically two aspects of the same unsteady aerodynamic flow field to be treated by a single time-dependent investigation. The main difficulty of such a combined approach, in a numerical simulation, is the length scale range to be resolved, which can cover several orders of magnitude.

Within AeroTraNet, a new code based on high-order compact schemes is being developed and validated against experiments, to model airframe flow and noise. This tool will be beneficial to AIRBUS SAS to design silent and aerodynamically efficient airframes for the next generation of wide-body civil aircraft, thus increasing the European competitiveness.

Research Methodology

The sustained growth in computing power has made the Direct Numerical Simulation (DNS) of aerodynamically generated sound increasingly feasible, giving the possibility of modelling the flow and the noise past representative engineering components. Numerical methods for sound generation use high-order accurate schemes (2), such as compact high-order Finite-Difference (FD) schemes, which aim at reducing the error in wavenumber space to model the exact dispersion relation associated with the governing equations in the continuous flow (3).

Objectives

The compact finite-difference approximation of the spatial derivatives makes their parallelization challenging. This HPC-Europa2 project aimed at optimizing the code for the specific machine used, the IBM Power 6 (SP6), and at implementing an efficient MPI parallelization.

Achievements

In the first part of this visit, the GNU Autotools have been added to the compilation stage of the new code. The GNU Autotools are packages used to solve the software portability problem, such as hardware, operating system and compiler differences. Specifically, these tools automate the selection of hardware specific compiler flags across different architectures.

The scalar code has been tested on the classical Computational AeroAcoustics (CAA) benchmark problem of an acoustic pulse expanding in a two-dimensional unbounded domain (Fig. 1) and compared against the available analytical solution (Fig. 2) (4).

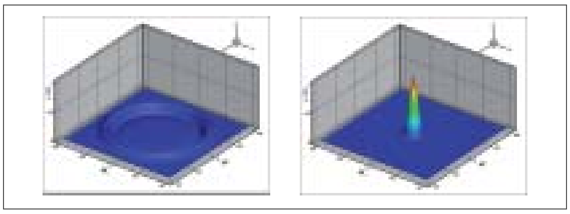

Fig. 1. – Propagation of a two-dimensional acoustic pulse. a) Initial state of non-dimensional density perturbation at $t/t_0 = 0$; b) Final state of non-dimensional density perturbation at $t/t_0 = 30$.

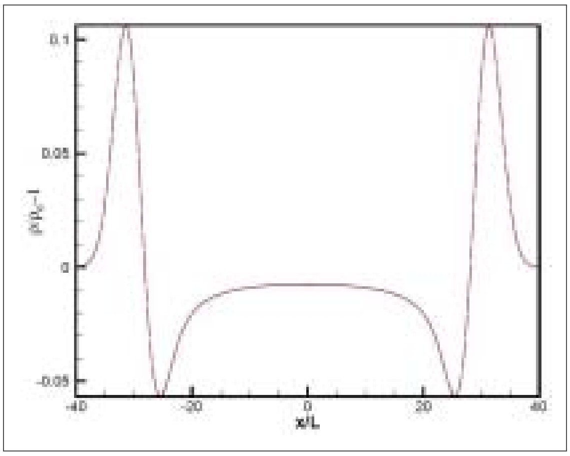

Fig. 2. – Density perturbation along the $y = 0$ line; dotted black line $(\cdots)$ numerical prediction, long dash red line $(--)$ analytical solution.

The code has been memory-checked with valgrind and profiled using gprof to detect the bottlenecks. Optimization techniques were used to tune the code on the IBM Power 6 processor. The optimized scalar code gave a speed-up of 24 times compared to the non-optimized version. The hpmcount, an IBM hardware performance tool that counts the floating-point performance, ranked the tuned version of the code in category 4 of 6. The scalar code was an excellent base for the parallelization performed in the second visit (5).

References

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